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RESPONSIBILITY FOR POOR POWER-FACTOR CAPACITOR OPERATION AND REPAIR

R. N. Shusterman, S. T. Mortirosov,
M. M. Morosov, D. S. Chernichkin

/The following three letters to the editors of Promyshlennaya Energetika and the editors' comment following them may be of interest in so far as they throw light on the quality of Soviet-made static power-factor capacitors, the quality of capacitor installation and maintenance techniques, and the problem of assigning responsibility for the repair of capacitors which have gone out of commission and for the production of spare parts.

Figures referred to are appended./

Letter From Engineers R. N. Shusterman and S. T. Mortirosov, Baku Order of Lenin Machine Building Plant imeni Lieutenant Shmidt

Static capacitors are of great importance in increasing the power factor and reducing losses in electric power transmission lines. However, early model static power-factor capacitors show low quality of manufacture and had short useful lives, the overwhelming majority breaking down within 2 to 3 years after installation.

The task of getting batteries of static capacitors back into operation is considerably complicated by the lack of any precise data on reasons for breakdown, procedures for their repair, or methods for operating them after reinstallation.

The operating experience of power engineers at the Baku Order of Lenin Machine Building Plant imeni Lieutenant Shmidt with reclamation of static capacitors which have broken down as indicated below.

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In 1942, the plant assembled and installed a battery of type KK-6-2 static capacitors, rated at 6 kv and a total power of 700 kvar. Only a portion of the capacitors were installed, the others being used as replacements when breakdowns occurred.

Despite the fact that the capacitors were adequately ventilated and disconnected from the network on hot summer days, they still broke down; by 1946, all 60 capacitors had become inoperative. Notwithstanding the fact that each bank was individually protected with a fuse of copper wire 0.1 mm in diameter, 4 banks burned out with an explosion, for the most part while the battery was being switched in.

The average useful life of a capacitor did not exceed 2.5 to 3 years.

Attempts were made to restore capacitors which had broken down by replacing burned out sections with repaired sections taken from other banks, but these capacitors were short-lived and broke down very quickly (within 2 to 3 weeks).

Attempts were then made to connect all repaired sections in parallel and to operate them at 2 kv (the operating voltage of the first section is 2 kv), but these capacitors were also unreliable in operation.

We then attempted to determine whether the short life of these capacitors after re-installation was due only by faulty repair technology or defects of the dielectric, as Engineer B. A. Polyakov stated, or whether there were other reasons.

A capacitor consists of a number of sections (in our case, no more than 15), each section operating at 2 kv, and connected in parallel-series groups (Figure 1). The voltage on a capacitor, and consequently on each section, must not exceed 110% of the rated value. Uniform voltage distribution among groups in series requires that the capacitance of these groups be identical. However, the capacitances of different groups vary somewhat, causing nonuniform distribution of voltages.

If the line voltage increases (e.g., at night), even if it does not exceed the allowable 10%, the voltage on some series group may exceed the maximum permissible. Long operation of such a capacitor leads to a breakdown in the insulation between plates of some section of the group. Such a breakdown of one section causes the voltage at the other two sections to increase to 1.5 times the original value (Figure 2). If the fuse on this bank does not burn out, or if attempts are made to replace the fuse and put the capacitor into operation, then one of the two sections still operating on the group voltage must certainly burn out as a result of the intolerably high voltage and will shunt out the whole group (Figure 3). The voltage on the remaining group rises to three times the original value and one of its sections will also burn out.

Thus the fundamental reason for a group of capacitors breaking down is evidently nonuniform voltage distribution among the sections.

Apparently the Capacitor Plant devotes insufficient attention to the exact matching of capacitances in series-connected groups; at least this is the logical conclusion to reach when one encounters banks in which series groups consist of different numbers of sections of different capacitances, or completely identical banks with the same number of identical sections having different capacitances according to the nameplate data.

An equally important factor is the insufficiently reliable dielectric between plates, which breaks down at comparatively low overvoltages. This insulation should possess a sufficient safety factor to eliminate the possibility of insulation breakdown even when the voltage on the capacitor increased by more than 10%.

The need to preserve equality of capacitances in series groups of capacitors whose sections are parallel-series-connected raises obstacles when one undertakes repair of capacitors by replacing burned-out sections with whole sections taken from other capacitors; it is difficult to find sections with identical capacitance out of a limited number of non-standard sections.

Neither is it practical to repair capacitors by unrolling the burned-out section to the place of breakdown, since the capacitance of such a section becomes very different from the original value, and this will again cause nonuniform voltage distribution.

The most effective means for repairing burned-out sections is to disconnect them by merely removing their leads. To equalize capacitances by groups it is sometimes necessary to disconnect good sections as well. The leads of these sections should be insulated, since good sections can be used again in subsequent repairs.

There is reason to suppose that further operation of the capacitors will cause breakdown of a section in the group which escaped damage before the repair operation, since this group would have been subjected to intolerably high voltage for a certain period.

Reliable operation of capacitors returned from repair at the original voltage can not be guaranteed, since in repair old sections are used which have already shown themselves to lack sufficient reliability in operation, and have for some period been subjected to excessively high voltage.

This should explain the fact that repaired capacitors have again broken down after a short period. The operating voltage on these capacitors must therefore be reduced.

Such a battery will be most effectively utilized in a star connection, thus giving equal distribution by phase.

At present, our battery has been reinstalled and is operating in a star connection.

Letter From M. M. Morosov, Candidate of Technical Sciences, Director of Capacitor Plant

The question of the useful life of static capacitors, the reduction of their breakdown rate, and the feasibility of repairing them are all of urgent importance. Since at this time insufficient data exists on their behavior in operation, all endeavors of plant power engineers to share on the pages of this journal their experience in repairing capacitors and their ideas on possible reasons for breakdown of capacitors must be eagerly welcomed.

The Capacitor Plant's viewpoint on repair problems is set forth in "Instructions No 91-51 on Maintenance of Capacitors for Raising the Power Factor at 50 Cycles.

/Apparently not all of the readers of Promyshlennaya Energetika are familiar with the contents of "Instructions No 91-51," published by the Central

Bureau of Technical Information, Ministry of the Electrical Industry USSR, in 1951, since the editors published excerpts from these instructions along with the letters. These excerpts are not included in this report.7

It is characteristic of the articles on power-factor capacitors by qualified specialists published in Promyshlennaya Energetika during 1951 (including Polyakov's, although in the plant's opinion some of Polyakov's proposals are contestable from engineering and economic viewpoints) that individual types of capacitor damages are examined, but no light is shed on the reasons for damage and especially the reason for breakdown of individual sections of capacitors during operation. This is no accident, since the problem of capacitor breakdown in operation still requires serious study.

Notwithstanding the urgent need for investigating and exchanging experience on the operation of static capacitors, the communication of Shusterman and Mortirosov supplies little concrete material in this direction.

It is well known that nonuniform voltage distribution in sections connected in series and incorrectly matched as to capacitance leads to increased voltage across individual sections and all the ensuing consequences. Evidently this is what happened at the Baku Order of Lenin Machine Building Plant imeni Lieutenant Shmidt during repair of capacitors, accompanied by unsatisfactory execution of the repair itself. Matching the capacitances of sections when they are to be connected in series receives primary attention at the Capacitor Plant.

Shusterman and Mortirosov state that nonuniform voltage distribution is evident from the fact that in completely identical banks with equal numbers of identical sections there is variation in capacitances, according to nameplate data. This is completely unfounded. Even when equal distribution voltage among series sections is fully maintained, capacitances of capacitors identical with respect to size and number of sections may deviate by $\pm$ 5% to $\pm$ 20% from calculated capacitance. The insulation between plates has a short-time electric strength of six to seven times the working voltage. The test value is three times the operating value. Consequently, this far exceeds those voltages referred to by Shusterman and Mortirosov, who were considering the possibility of voltage increases of more than 10%.

Unfortunately, Shusterman and Mortirosov do not describe the ventilation used, nor do they include temperature data or data on capacitor breakdown by months of the year. The very fact that capacitors were disconnected on hot days suggests that the ventilation was unsatisfactory and did not provide the proper ambient temperature, which is especially important in the Baku region. Explosive breakdown of capacitors is evidence that they were unsatisfactorily operated and protected. Apparently the capacitors were hooked up without checking their capacitances and with some of the sections shorted.

As to problems of capacitor repair, Shusterman and Mortirosov, speak only of matching the sections. It is not known whether vacuum processing was used, what the characteristics of the oil were, whether there were conditions for absorption of moisture, etc.

Shusterman and Mortirosov correctly state that it is impossible to guarantee reliable operation of capacitors after repair at the previous operating voltage; however, this is not because old sections are used. In taking up the problem of repairing capacitors which have become inoperative as a result of the breakdown usually of one and less often of two or three of its sections, many plant workers do not pay attention to the type of breakdown or the conditions under which it occurred. As a rule, breakdowns occur after these capacitors have been in operation for some time and are evidence either of defects in insulation which did not show up during plant short-time

testing or of abnormal operating conditions. In either case, the first to break down are sections containing weak spots, since oil-impregnated paper is a nonhomogeneous dielectric. It the dielectric of such a capacitor retains an acceptable loss angle (not more then 0.5%), a repaired capacitor retains an acceptable loss angle (not more than 0.5%), a repaired capacitor can be expected to operate for a long time, providing the repair procedures we recommend are observed.

If, on the other hand, the dielectric for some reason does not retain the maximum acceptable loss angle, lasting positive results cannot be expected even if the recommended repair technology is observed and the capacitors are operated at a somewhat lower voltage.

Letter From D. S. Chernichkin, Deputy Minister of the Electrical Industry

Reliability of repair paper-oil capacitors in operation can be assured only by strict observance during repair of procedures basically analogous to those used in the manufacture of new capacitors. This implies the special processing of transformer oil, vacuum drying, clean working spaces, and a number of other conditions which apply specifically to the production of paper-oil capacitors and are incompatible with conditions existing in plants which repair electrical machines. Therefore, the Ministry of the Electrical Industry is unable to undertake repair of paper-oil capacitors at existing electrical repair plants. Nor does it seem possible to organize special plants or shops for repair of paper-oil capacitors in view of the Ministry of Electrical Industry's lack of free production facilities.

At the same time, the Ministry of the Electrical Industry sees merit in Engineer B. A. Polyakov's proposal that the facilities of operating organizations, primarily the "energosbyts" (administrations of electric power sales of regional electric power administrations) of the Ministry of Electric Power Stations, be used for the repair of paper-oil capacitors, as they are the organizations most interested.

The Capacitor Plant of the Ministry of the Electrical Industry can give these organizations the necessary engineering assistance by drawing up technical instructions on the repair of paper-oil capacitors as well as programs and norms for testing the capacitors after repair. In addition, the plant should offer systematic consultation on all technical questions.

Comment by the Editors

In view of the great interest shown by industrial power engineers in problems of the repair of static power-factor capacitors, the editors have published the above letters.

The editors disagreed with D. S. Chernichkin's proposal to organize repair of paper-oil capacitors only in operating organizations, and primarily "energosbyts" of the Ministry of Electric Power Stations. "Energosbyts" of this ministry are offices for state control and supervision of electric power consumption and the technical state of consumers' power installations. "Energosbyts" do not have the necessary facilities for repair of either electrical equipment or capacitors.

Therefore, the editors support B. A. Polyakov's proposal to organize repair of paper-oil capacitors within regional power repair trusts of the Ministry of the Electrical Industry. If these trusts are supplied with spare impregnated sections by the Capacitor Plant and spare insulators for leads by the Insulator Plant and if they are equipped with impregnating vats for drying and impregnating, then they will be in a position to undertake any capacitor repair work.

The editors once more request that the Deputy Minister of the Electrical Industry give this matter additional consideration and obligate power repair trusts of his ministry to perform repair of paper-oil capacitors.

/In connection with the above remarks, it should be noted that the journal Promyshlennaya Energetika is an organ of the Ministry of Electric Power Stations, while the Ministry of the Electrical Industry is not represented on its editorial board./

Until this matter is finally resolved, the editors recommend that organizations which perform repairs on capacitors should take all problems relating to capacitors to the Capacitor Plant of the Ministry of the Electrical Industry, which can provide needed consultation on all technical matters pertaining to capacitor repair.

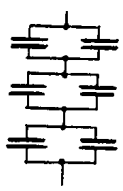

Figure 1

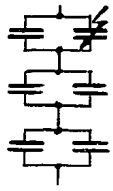

Figure 2

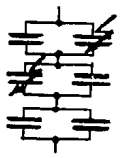

Figure 3

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